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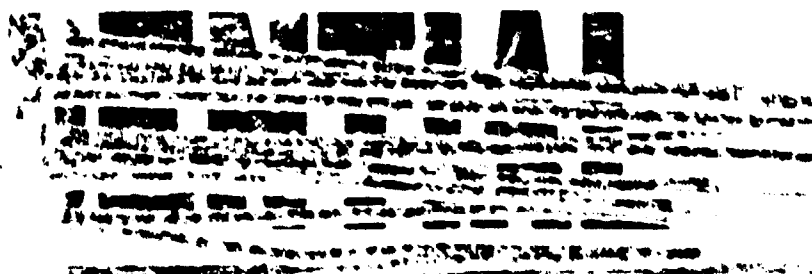
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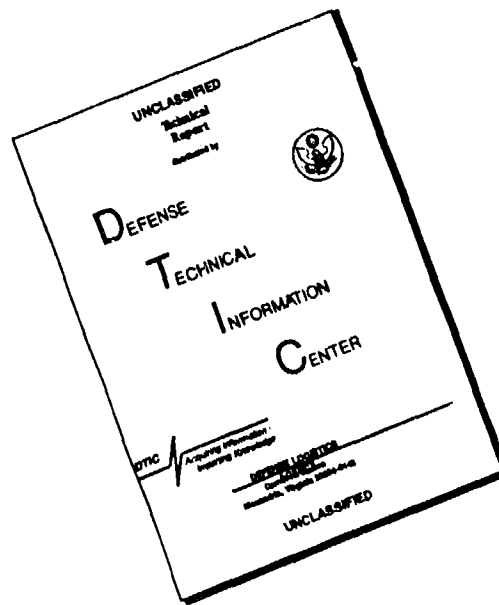
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Protection Branch Memorandum Report No. 11-59

EVALUATION OF FOUR TYPES OF USN PROTECTIVE SUITS (U)

26 November 1958

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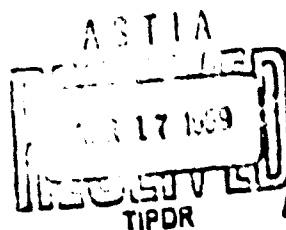
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Memorandum Report No. 11-59

Evaluation of Four Types of USN Protective Suits (U)

(U) In accordance with Interservice Supply Support Agreement #963-3166 issued to the BW Laboratories, Fort Detrick, Maryland by the Clothing and Textile Division, U.S. Naval Supply Research and Development Facility, Bayonne, N.J., four types of protective suits were submitted for BW evaluation. Three of these suits were different models of the USN Experimental Decontamination Suit. The fourth suit was an experimental Wet Weather Outfit. A description of each of the four types follows:

(U) Type 1 - (D7C2). This suit is a one-piece impermeable garment made from standard butyl-coated fabric with attached footgear and detachable hand wear (Figure 1). The front entry closure is made impermeable by a combination of a gusset seal and water-proof zipper. The hood with a MIV protective mask attached is an integral part of the suit.

(U) Type 2 - (D7C4). This suit is the same as Type 1 except that the MIV mask is detached from the suit (Figure 2). The suit has an attached hood which is sealed to the mask facepiece by means of a specially designed rubber closure arrangement (Figure 3).

(U) Type 3 - (D7C3). This suit is the same as Type 2 except that the suit is permeable (Figure 4). This type has a layer of impregnated filter material both in the front and back of the suit (Figure 5). The purpose of this modification is to provide some degree of ventilation to the wearer.

(U) Type 4 - This suit is a wet weather outfit fabricated from a neoprene coated material, complete with parka and overall-type trousers (Figure 6).

(U) Three suits of each type were received for evaluation. Each of the protective suits was worn over a suit of two-piece cotton long underwear. Cotton gloves and socks completed the ensemble. As agreed by Mr. Edward Cherowbrier, Project Officer, U.S. Naval Supply Research and Development Facility, and Chief, Protection Branch, Physical Defense Division, each of the twelve suits was tested in duplicate.

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TEST PROCEDURE

(U) The tests were conducted over a six day period with one suit of each type tested each day. Four male subjects, each wearing a different type of suit, were exposed each day in a cloud chamber room 16' x 9' x 10' to an aerosol of *B. globigii* spores. The mass median diameter (MMD) of this aerosol was 7.1 microns with 95% of the particulates between 1 and 5 microns. The challenge aerosol concentration ranged from 1.5 to 2.5×10^5 spores per liter. The chamber was operated at a temperature of 20°C.

(U) The sampler utilized in this evaluation consisted of a 3 cm² cotton twill rectangular cloth patch attached to a 3-inch strip of $\frac{1}{2}$ -inch double-coated pressure sensitive tape. These patch samplers were taped to the skin and underwear, respectively, in the following four anatomical areas: scapular and axillary (lower neck), epigastric and median dorsal (waist), ulnar antibrachial (wrist) and lower femoral (upper knee). The exact patch locations are shown in Figure 7. A patch sampler was also used in the head area. This sampler was placed on the mask harness and the spores recovered from this sampler were considered as penetration to the skin. Four samplers also were attached to the outside of the protective suits, two on the chest and one on each thigh.

(U) Upon entering the exposure chamber (Figure 8) the subjects were seated for a 1-hour period except when performing the following series of exercises at 15-minute intervals:

1. Touch toes twice, hold for 5 counts each.
2. Arm exercise.
 - a. Hands on hips
 - b. Extended arms to side
 - c. Extended arms forward
 - d. Extended to side
 - e. Extend over head
 - f. Extend to side
 - g. Hands on hips
 - h. Arms down
3. Deep knee bend twice, hold for 5 counts each.

(U) At the conclusion of the test period, the subjects left the chamber through two airlocks which were constantly airwashed. The outer layer patch samplers were removed in the first airlock and all underwear and skin samplers in the second airlock. The rectangular cloth patches were then aseptically removed from the tape and transferred to 10 milliliter water blanks. Following this, they were heat-shocked for 10 minutes at 60°C and then shaken for 10 minutes. Agar pour plates of the water solution containing the resuspended spores were used to determine the total number retained by each sampler.

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(U) During each day's test, a control subject was dressed in one of the test suit ensembles with the patch samplers in place. This control subject remained in the airlock instead of entering the exposure chamber, but otherwise followed the test procedure. The purpose of this test control was to ascertain that the sampling techniques employed were sterile.

RESULTS AND DISCUSSION

(U) The geometric mean per cent leakages for each of the twelve suits are presented in Table I. These means were computed by adding the under-wear and skin patch spore counts so that the total leakage at a given sampling area might be determined. The ratio of this total to the average count obtained from the four outside layer patch samplers was converted to per cent leakage and then to logarithms for statistical analysis. The analysis of variance is given in Table II.

(U) This analysis shows that differences among suit types were highly significant. Type 1 offered the greatest protection followed in order by Types 2, 3, and 4. The penetration through Type 1 suits was significantly lower than that for the other types. Penetration through Type 2 was significantly less than that for Types 3 and 4. The leakage difference between Types 3 and 4 was not significant. Geometric means expressed as per cent reduction (i.e., 100% minus per cent leakage) are listed for the four types:

Type	Per Cent Reduction
1	99.998
2	99.758
3	98.652
4	96.254

(U) With the exception of Type 1, there was appreciable variation of suits within type. However this variation was not statistically significant when compared to the random variation encountered throughout the tests.

(U) Leakage at the different sampling locations varied significantly among suit types (Table II, line 14). These differences are undoubtedly due to the various types of suit design. This is substantiated by the fact that the results show that the greatest penetration of Types 2 and 3 suits occurred at the sampling locations of greatest proximity to the most vulnerable part of the respective suits. To illustrate, Type 2 yielded the greatest penetration at the lower neck. Patch samplers at this location collected the *B. globigii* spores penetrating the rubber closure arrangement which was designed to seal the suit to the periphery of the detached MKV mask. Type 3 which has a permeable layer of impregnated filter material in the front and rear of the waist area showed the greatest penetration at these sampling locations (7.69%).

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A filter penetration test performed on a double layer of this impregnated material showed that the material allowed a *B. globigii* spore penetration of 7.36 per cent. Thus, the leakage of this type of suit at the waist area is undoubtedly due to the ineffectiveness of the filter material against particles in the 1 to 5 micron size range. On the other hand, Type 1 demonstrated no significant difference in leakage at any of the five sampling areas. This type, which is impermeable with the mask as an integral part of the suit, does not possess any feature which can be considered as potentially vulnerable. Type 4, a wet-weather outfit, was not primarily designed as a CBR protective suit. However, it was included in this evaluation in order to obtain an indication of the amount of protection which could be expected if worn in a contaminated area.

(U) The geometric mean per cent penetration was also computed at each sampling location for the skin and underwear layers, respectively. These means are given in Table III.

(U) The average spore count on the daily control patch samplers was less than 0.1. This indicates that not only were the individual samplers sterile, but also demonstrates that the technique of placing the samplers and subsequently removing them was satisfactory.

(C) The BW protection afforded by Type 1 and 2 experimental suits compares very favorably with that of the Chemical Corps M3 Protective Suit. This latter suit gives the wearer 99.5 per cent protection. Since the M3 Protective Suit provides adequate protection for use by specially trained decontamination personnel, USN Experimental Decontamination Suit models 1 and 2 (D7C2 and D7C4) can also be considered to be adequate for use in BW contaminated areas.

(C) The Wet-Weather Outfit (Type 4) affords approximately the same amount of BW protection as an U.S.A. fatigue uniform when worn with boots, socks, gloves and M3A1 Protective Mask complete with an impregnated hood.

DECONTAMINATION STUDIES

(U) Four of the twelve suits including gloves and masks were decontaminated three times while the remaining eight ensembles were decontaminated once. These items were exposed to a concentration of 195 milligrams of ethylene oxide per liter of space for 12-hours. Following this, they were aerated for 12-hours prior to use. A visual inspection was made of each suit after decontamination. No adverse effects which could be attributed to the ethylene oxide were observed.

(U) In order to prevent ethylene oxide adsorption by the canister charcoal layer, the canisters were removed from each mask during the exposure period. The exterior surface of these components was decontaminated by wiping thoroughly with a bleach solution containing 1000 ppm available chlorine.

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(5)

(U) Table I shows that the overall geometric mean per cent BW penetration was 0.253 per cent for replicate 1 (before decontamination) and 0.226 per cent for replicate 2 (after one or more decontaminations). The effect of decontamination as indicated by the replicate mean square (line 1, Table II), was negligible. No significant differences among suit types, which would indicate their inability to withstand ethylene oxide decontamination were detected.

ACKNOWLEDGEMENTS

(U) The excellent technical assistance rendered during these tests by Melvin E. Filler; James Lewis, HQI, USN; Joseph A. Milo, Jr., HQI, USN; and Hulett Register, HQI, USN is gratefully acknowledged. The statistical analysis of the data was performed by Charles W. Riggs, Mathematics Division, Fort Detrick.

SUMMARY

(U) Four types of USN protective suits ~~have been~~ tested in an aerosol of *B. p. glaberrima* spores. Three of these types were different models of the USN Experimental Decontamination Suit. The fourth type was a Wet Weather Outfit.

(U) A statistical analysis of the results showed that differences among suit types were highly significant. Type 1 (impermeable with integrated mask) offered the greatest protection followed in order by Type 2 (impermeable with detached mask), Type 3 (permeable with detached mask) and Type 4 (wet weather outfit). The penetration through Type 1 was significantly lower than that for the other types. Penetration through Type 2 was significantly less than that for Types 3 and 4. The leakage difference between Types 3 and 4 was not significant. Leakage at the five sampling locations varied significantly among suit types. These differences are undoubtedly due to the various types of suit design, since the greatest spore penetration for each type occurred in the most vulnerable area.

(U) No adverse effects on the twelve suits as a result of ethylene oxide decontamination were visually observed or indicated by the test results.

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TABLE I.

Geometric Mean Per Cent Penetration for Four Types of USN Protective Suits
(Combined Underwear and Skin Layer Totals) (U)

Note: Test agent - B. globigii; Type of sampler used - 3 cm² cotton twill patch

Type	Suit	Sampler Location					Suit Means	Type Means
		Head	Lower Neck	Waist	Wrist	Upper Knee		
I	1	0.004	0.002	0.002	0.00	0.002	0.002	0.002
	5	0.008	0.027	0.000	0.000	0.000	0.002	
	9	0.009	0.000	0.000	0.000	0.010	0.002	
		<u>0.007</u>	<u>0.003</u>	<u>0.000</u>	<u>0.000</u>	<u>0.002</u>		
II	2	0.235	10.129	2.814	0.808	1.478	1.516	0.242
	6	0.003	1.194	0.709	0.180	0.220	0.169	
	10	0.173	0.737	0.119	0.006	0.004	0.055	
		<u>0.094</u>	<u>2.074</u>	<u>0.620</u>	<u>0.101</u>	<u>0.115</u>		
III	3	0.362	3.580	2.712	0.239	0.218	0.712	1.348
	7	0.147	6.721	12.399	2.635	3.706	2.607	
	11	0.017	4.202	13.519	1.356	2.883	1.317	
		<u>0.098</u>	<u>4.858</u>	<u>7.890</u>	<u>0.949</u>	<u>1.327</u>		
IV	4	0.724	3.680	0.033	3.872	11.389	1.317	3.746
	8	1.967	9.626	2.482	4.666	2.873	3.630	
	12	6.886	22.209	15.849	11.899	5.551	10.989	
		<u>2.143</u>	<u>9.231</u>	<u>1.359</u>	<u>5.990</u>	<u>5.664</u>		

Replicate

% Penetration

1 (Before Decontamination)

0.253

2 (After one or more Decontaminations)

3.228

Confidence Limit Factors (95% Level)

For Type X Position Means

For Type Means

4.5

Type I

2.9

Types II, III, IV

5.5

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TABLE II.

Analysis of Variance for Four Types of USN Protective Suits (U)

Log (Per Cent Penetration + 0.001)

Line No.	Source of Variation	df	Mean Square	Error Line	F	Prob.
1	Replicate	1	0.06093	9	<1	NS
2	Among Suits (S)	11	17.16731	-	-	-
3	Type (T)	3	57.44328	8	20.9	<1%
4	Suits/Type I	2	.01222	11	<1	NS
5	Suits/Type II	2	5.32882	-	-	-
6	Suits/Type III	2	.79318	-	-	-
7	Suits/Type IV	2	2.12108	-	-	-
8	Pooled lines 5,6,7	6	2.7476	11	2.33	>20%
9	R X S	11	.92264	-	-	-
10	R X T	3	.24131	11	<1	NS
11	R X S/T	8	1.17814	-	-	-
12	Position (P)	4	2.78913	15	4.37	<1%
13	S X P	44	.88550	-	-	-
14	T X P	12	1.54545	15	2.42	<5%
15	S/T X P	32	.63801	18	1.53	>10%
16	R X P	4	.30377	17	<1	NS
17	R X S X P	44	.42615	-	-	-
18	Pooled lines 16 & 17	48	.41595	-	-	-

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TABLE III.

Geometric Mean Per Cent Penetration for Four Types of USN Protective Suits
(Underwear and Skin Layers Computed Separately) (U)

Notes: Test agent - B. globigii spores; Type of sampler used - 3 cm² cotton
will patch

Suit Type	Layer	Sampler Location					Type x Layer Means
		Head	Lower Back	Waist	Wrist	Upper Knee	
I	Underwear	-	0.003	0.001	0.000	0.002	0.001
	Skin	0.007	0.000	0.000	0.000	0.000	0.001
II	Underwear	-	1.518	0.252	0.086	0.080	0.234
	Skin	0.054	0.505	0.096	0.013	0.035	0.065
III	Underwear	-	4.097	6.415	0.822	0.976	2.143
	Skin	0.098	0.120	1.019	0.063	0.135	0.258
IV	Underwear	-	6.813	0.928	5.979	4.728	3.542
	Skin	2.143	1.907	0.370	0.006	0.759	0.368

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Figure 1
Exp Decon Suit D7C2



Figure 2
Exp Decon Suit D7C4



Figure 3
Rubber Closure Arrangement
used in D7C3 and D7C3 suits



Figure 4
Exp Decon Suit D7C3

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Figure 5

Impregnated Material used in D7C3 Suit



Figure 6

Wet Weather Suit

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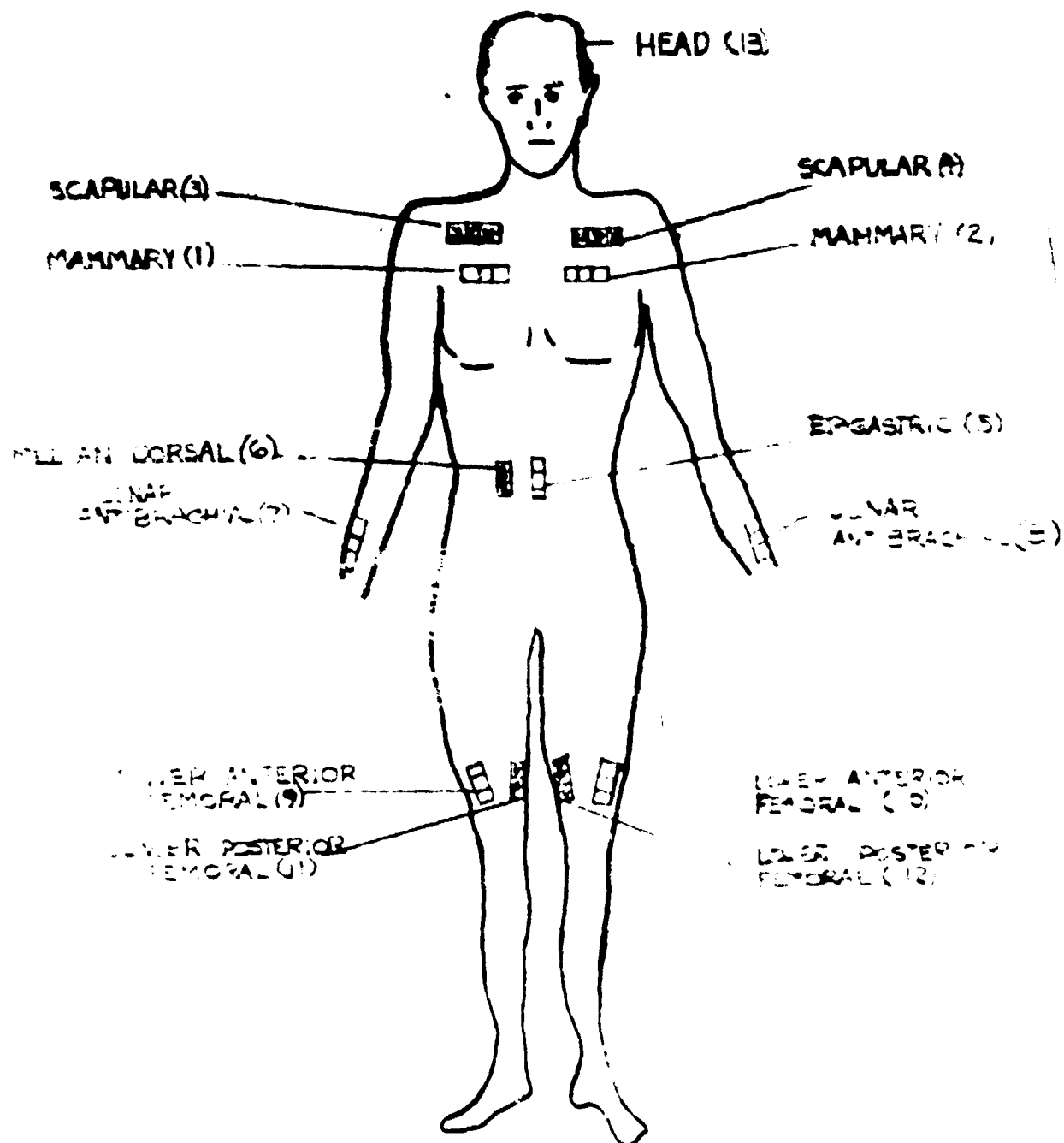


FIGURE 7 PATCH SAMPLER SITES